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Environmentally friendly turbo jet aerator for sustainable multitrophic aquaculture

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Abstract. Aquaculture is an oxygen-dependent business; heterotroph biomass production is proportional to the oxygen supply to the aquaculture pond, therefore, intensive and supra-intensive aquaculture requires a large supply of oxygen. The use of paddle wheel aerators and the types of aerators available in the market today are generally wasteful in terms of energy use. This poster presents the test results of the Prototype Turbo Jet Aerator, which is named RA-TJA-SG1. This submersible aerator prototype was designed to be able to produce large amounts of oxygen with a small energy consumption (40 watts) using sustainable solar energy. Laboratory test results indicated that the RA-TJA-SG1 is able to increase the content of the concentration of dissolve oxygen in seawater at different salinity to the ideal concentration for intensive and supra intensive shrimp culture.

1. Introduction

Shrimp farming has developed progressively, from traditional, traditional plus and semi-intensive systems [1,2] low technology input to super intensive systems [3] high input technology. This super intensive system can cultivate whiteleg shrimp *Litopenaeus vannamei* with a density of 750 to 1,250 fish per m^2 [3,4].

In intensive whiteleg shrimp culture, paddle wheel aerator oxygen is used as a source of oxygen. High stocking density requires a certain type of aerator, and a large number of paddle wheel aerator oxygen to meet the shrimp needs for oxygen [5,6]. The high density of shrimp must be balanced with the input of oxygen in large quantities.

Oxygen is an essential factor in cultivation because aquaculture is an oxygen-dependent business; heterotroph biomass production is proportional to the oxygen supply to the aquaculture pond, therefore, intensive and supra-intensive aquaculture requires a large supply of oxygen. Oxygen is a major determinant of success in the aquaculture [7-10]. In shrimp farming, besides being needed by shrimp, oxygen is used also by aerobic bacteria in the nitrification process using ammonia. Nitrification process will reduce the concentration of ammonia which is harmful to shrimp [11].

The input or addition of oxygen usually comes from the paddle wheel aerator oxygen, blowers, and the like. During the 60 day maintenance period until harvest, 3-4 units of paddle wheel aerator oxygen are required for each cultivation unit [12] to be able to produce optimal dissolved oxygen for whiteleg shrimp. The effect of using paddle wheel aerator oxygen is a lot of increasing electricity consumption, which has an impact on production costs. Paddle wheel aerator oxygen is one of the four production factors in whiteleg shrimp ponds [13].

In shrimp culture, to produce one ton of shrimp, one paddle wheel aerator with one horse power (735.5 to 745.7 watts) is required. This makes production costs high, unaffordable for small-scale business, and less environmentally friendly. Therefore, a more appropriate technology support system is needed to support aquaculture development, especially multitrophic aquaculture development.

The RA-TJA-SG1 is an energy-efficient aerator, which is designed to produce oxygen equivalent to one paddle wheel aerator with one horse power. This turbo jet aerator has a brushless DC (BLDC) motor as an oxygen generator. The motor is specially designed so that it can use energy from solar panels or batteries. The main components of the turbo jet aerator are the motor, a turbine to inject air into the water, and the chassis. The aerator jet turbine motor is designed to be waterproof so that it can be placed in the water. The position of the turbine in the water makes the motor cooler and extends its usable period. Power consumption of the motor is 40 watts with 12-24 volt operating voltage. The turbine in the aerator jet can increase dissolved oxygen in water to 6 ppm. The motor uses an electrical control system (ECS) and a potentiometer to adjust rotations per minute (RPM) so that the dissolved oxygen content in the water can be adjusted. This study aims to test the ability of the RA-TJA-SG1 to produce dissolved oxygen in water at different salinity

2. Materials and Methods

The efficiency of the RA-TJA-SG1 was tested at four levels of salinity, namely 30, 35, 40 and 45 ppt. The trials were carried out using tanks with a diameter of 55 cm and a height of 94 cm. Tanks were filled with seawater as high as 90 cm. To obtain the desired salinity, seawater was naturally evaporated in tanks (size 100 x 200 x 90 cm). After the desired salinity was achieved, seawater was put in four different tanks, then closed for 15 days so that the oxygen content can naturally drop to the lowest level. Before starting the test, the dissolved oxygen in each tank was measured first. The value of the measurement results was used as a standard or control value. The trial time was calculated starting from the RA-TJA-SG1 engine is on. Oxygen content was measured every three minute intervals. Dissolved oxygen concentration was measured three times. The test was stopped when the dissolved oxygen content was constant. Since only one prototype was available, the trials were carried out in stages from lowest to highest salinity

3. Results

The test results of the RA-TJA-SG1 (Figure 1) at salinity of 30, 35, 40, and 45 ppt indicated that there was an increase in oxygen between before and after the RA-TJA-SG1 application (Table 1, Figure 2). The experiment was stopped at the ninth minute because the dissolved oxygen content in water at all salinities levels were constant. The concentration of dissolve oxygen between before and after RA-TJA-SG1 application were significantly different ($P < 0.05$). The concentration of dissolve oxygen after 3, 6 and 9 minutes were not significantly different ($P > 0.05$). The concentration of dissolve at different salinity (30, 35, 40 and 45 ppt) were not significantly different ($P > 0.05$).

Figure 1. RA-TJA-SG1 application at different water salinity.

4. Discussion

RA-TJA-SG1 was able to increase the concentration of dissolve oxygen to more than 7 ppm in a very short time, less than three minutes. Besides being able to increase the concentration of dissolve oxygen very quickly, RA-TJA-SG1 can produce oxygen constantly because it is in the water.

This makes the RA-TJA-SG1 more effective, efficient and superior to the paddle wheel aerator oxygen that has been used in ponds [13]. The results of previous studies reported that the oxygen transfer rate by paddle wheel aerator oxygen fluctuates greatly and is influenced by the salinity of pond water [14]. The test results on a laboratory scale showed that the oxygen concentration obtained from RA-TJA-SG1 was not affected by water salinity.

Table 1. The concentration of dissolve oxygen before and after 3, 6 and 9 minutes of RA-TJA-SG1 application at different salinities

Dissolved Oxygen (ppm)	Before Testing (Mean±STD)	After Three Minutes		After Six Minutes		After Nine Minutes	
		Results(Mean±STD)	Differences (Mean±STD)	Results (Mean±STD)	Differences (Mean±STD)	Results (Mean±STD)	Differences (Mean±STD)
Salinity 30 ppt	3.39±0.10	8.43±0.35	5.04±0.31	9.10±0.04	5.71±0.08	8.14±0.74	4.76±0.64
Salinity 35 ppt	2.44±0.07	8.64±0.16	6.20±0.23	7.38±0.11	4.93±0.12	6.79±0.03	4.34±0.05
Salinity 40 ppt	3.97±0.22	9.12±0.04	5.15±0.19	8.82±0.36	4.85±0.15	7.25±0.06	3.28±0.28
Salinity 45 ppt	3.75±0.15	9.04±0.02	5.29±0.14	8.66±0.02	4.90±0.14	8.62±0.05	4.87±0.12

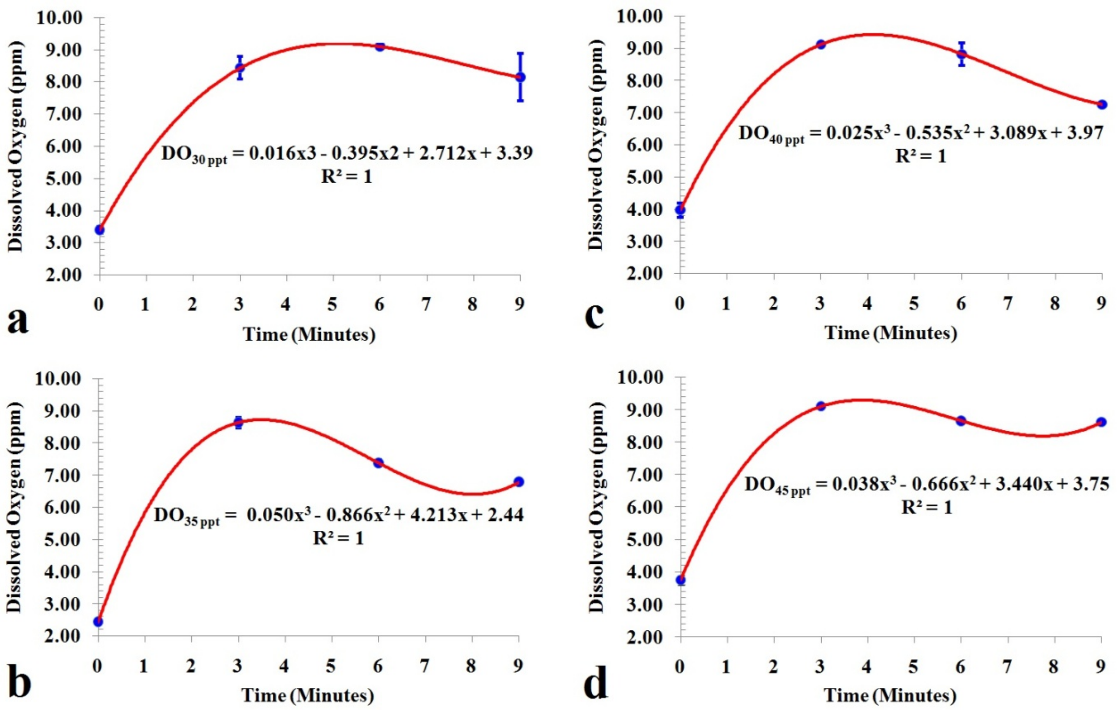

Figure 2. The oxygen concentration curve of RA-TJA-SG1 during the test at different salinities. 30 ppt (a), 35 ppt (b), 40 ppt (c), and 45 ppt (d).

The RA-TJA-SG1 is superior to paddle wheel aerator oxygen because it is a submerged turbo jet aerator. This makes the oxygen production of the RA-TJA-SG1 more constant and is not affected by technical or non-technical factors. This is very different from the oxygen production produced by paddle wheel aerator oxygen which is influenced by technical or non-technical factors [15], including flapping on the water surface (Fast et al., 1999, Roy et al., 2015), pond size, inconsistent operating hours [15], environmental conditions [16]. A constant oxygen transfer rate is very important from a technical aspect of cultivation [17] and operational costs during cultivation [18].

The RA-TJA-SG1 does not have technical and non-technical obstacles, as experienced by paddle wheel aerator oxygen. The test results in the laboratory show that RA-TJA-SG1 can produce a concentration of dissolve oxygen was ideal for intensive and supra intensive ponds. The oxygen content in the intensive cultivation of whiteleg shrimp in ponds ranges between 4 and 6 ppm [19], and super intensive with high stocking (750-1,250 ind / m2) was 5,48±1,25 ppm [20]. Meanwhile, intensive tiger prawns were optimal at 4-7 ppm [21]. The results of this test will be used to scale up the RA-TJA-SG1 to a commercial scale.

5. Conclusion

Laboratory test results indicated that the RA-TJA-SG1 is able to increase the content of the concentration of dissolve oxygen in seawater at different salinity to the ideal concentration for intensive and supra intensive shrimp culture.

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